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Asymmetry of individual and aggregate inflation expectations: A survey*

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Abstract

We conducted a simple, anonymous survey at the beginning of 2014, asking around 200 economists worldwide to reveal their expectations about US inflation. The outcome of the survey shows that a significant share of respondents revealed asymmetric inflation expectations and that the deviation from symmetry is sizeable. The aggregate distribution we obtain is moderately skewed to the right. Interestingly though, it is disagreement among respondents and not the asymmetry of their subjective distributions that drives the aggregate skewness. In fact, ignoring individual asymmetry changes little in terms of mean and variance of the aggregate distribution.

Keywords: inflation expectations, subjective distributions, asymmetry
JEL Classifications: E31, C46

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1 Introduction

Inflation expectations constitute a vital part of decision–making by companies, households and policymakers alike. The most common way to collect data on inflation expectations is by means of surveys, where respondents are asked to provide their inflation expectations by specifying a point forecast,[1] an interval[2] or an entire distribution of possible outcomes.[3] Numerous users of these surveys focus mostly on the first two moments of the distribution. Still, if the asymmetry of forecasters' subjective distributions is high and not taken into account, the point forecasts provide a poor description of forecasters' expectations. More generally, asymmetry contains information on how likely forecasters deem 'extreme' inflation rates and might explain the so called inflation scare observed in the bond market particularly in 1983–1984, see García & Manzanares (2007).

Characterizing asymmetry in the survey data is challenging. Consider for instance the Survey of Professional Forecasters (SPF). Given that the forecasters provide probabilities of inflation falling into specified 'bins', one needs to assume a parametric form of subjective distribution to obtain its moments. The literature has debated several candidate distributions starting with the normal (Giordani & Söderlind, 2003), which imposes symmetry, the skew-normal (García & Manzanares, 2007) and the generalized beta (see e.g. Engelberg, Manski & Williams, 2009; Clements, 2014). Additional difficulty is estimating parameters of the chosen distribution on a relatively small number of observed bins. These might be the reasons for which the literature offers little guidance on how high is the asymmetry of subjective distributions in surveys of inflation and how important is to account for those asymmetries when aggregating inflation expectations.

This paper tries to fill the gap by conducting and reporting a survey that directly tests whether subjective distributions of future US headline inflation are asymmetric and by exploring how these asymmetries affect the aggregate distribution. We conducted the survey during the transition of Fed leadership from Ben

[1] Consensus Economics survey and Blue Chip Economic Indicators survey are two important examples.

[2] For example, the Regional Network Company Survey conducted by the Swiss National Bank (SNB). Survey results are regularly published in the monetary policy report (in German), visit the following page.

[3] Most notably, the Survey of Professional Forecasters (SPF) conducted by the Federal Reserve Bank of Philadelphia.

Bernanke to Janet Yellen in the beginning of 2014. We asked the respondents to provide two intervals of expected inflation over the next two years: conditional on Janet Yellen being the Fed chair, and in a counterfactual scenario in which Ben Bernanke would have remained the chairman of the Fed. The political framing of the questions was intended to prevent participants from answering the survey as if it were a purely technical inquiry. In a second step, we simply asked them to give a probability of inflation being higher or lower than the midrange of a (randomly selected) interval that they have provided.

We document significant departures from symmetry of the subjective probability distributions. More specifically, about 60% of our respondents revealed asymmetric distributions with mean absolute deviation being equal to a probability mass of 0.19. We then impose parametric assumptions on subjective distributions to obtain an aggregate distribution. In terms of expected inflation, the results from our survey are comparable to the corresponding outcome of the SPF for the first quarter of 2014. By exploiting the design of our survey, we show that ignoring asymmetry of subjective distributions has little effect on the moments of the aggregate distribution. The aggregate distribution is moderately positively skewed, but we find that the aggregate skewness is driven by disagreement among respondents and not the asymmetry of their subjective distributions.

Our paper relates to the literature on the analysis of expectation surveys, such as the SPF. García & Manzanares (2007) find that the aggregate expectation distribution is mostly positively skewed and that accounting for asymmetry by imposing skew-normal densities leads to a better fit of subjective distributions. Lahiri, Teigland & Zaporowski (1988) find significant skewness in subjective distributions using a different data set that is also based on probabilities in 'bins'. Murasawa (2013) reports similar findings for household inflation expectations comparing the normal, skew-normal, and skew-t distributions. In the lab, Pfajfar & Žakelj (2016) find significant asymmetry in confidence intervals of expected inflation in different monetary policy environments but treatments which do not allow participants to specify asymmetric intervals perform better. Clements (2014) studies SPF data and reports that allowing for asymmetry in individual distributions has no significant effect on forecast means and variances. In line with the latter paper and using survey data, Bruine de Bruin, Manski, Topa & van der Klaauw (2011) find that the mean of individual distributions is an accurate statistic for expected inflation at the aggregate level. However, in many cases it offers a poor description of individual expectations. A different but related strand of the literature compares forecasters' point predictions with the central tendencies of their subjective probability distributions, generally finding that the two measures do not always agree (Engelberg et al. (2009), Clements (2010)). Our paper also relates to a rich literature in financial markets theory. De Bondt (1993) found skewness in subjective probability distributions of investors. This was also found in the lab by Du and Budescu (2007), who report skewness in participants' expected returns intervals depending on whether they expect asset prices to rise or fall.

The rest of the paper is structured as follows. Section 2 describes the survey and provides some illustrations for the inflation expectations of our respondents. In Section 3 we discuss the results of our survey by focusing first on the degree of asymmetry in expected inflation distributions and whether asymmetry is related to interval measures. We then impose the piecewise uniform distribution to derive moments of subjective distributions and aggregate expectations. In a simulation experiment, we investigate whether accounting for asymmetry matters for the aggregate distribution and what drives its skewness.

2 The survey

In this section we detail our survey methodology. We designed the survey to be short in order to get a maximum response rate. The target group comprised non-professional forecasters with an economic background, so that we could be sure that they were familiar with the basic concepts and knew who Ben Bernanke and Janet Yellen were. We sent invitations to complete the online survey by e-mail between December 2013 and February 2014, providing a link to a homepage hosted by the University of Zurich.

The survey was answered by 182 economists from the Federal Reserve System, the European System of Central Banks, Norges Bank, Riksbank, Stanford University, University of Chicago, Columbia University, University of California at Berkeley, Bocconi University, University of St. Gallen, University of Zurich and Swiss National Bank, among others. The online survey presented participants with four questions on three pages about headline inflation expectations in the US over the next two years.[4] Their answers were saved in a database. The estimated response

[4] We have chosen that forecast horizon as a 'golden mean' between very short-term expectations,

time was roughly 1.5 minutes.

An overview of the four questions is given in Table 1. The first question, "Do you have a background in economics and/or statistics?" (yes/no), was designed to test whether we were reaching the target audience and was used to select only those that actually did have such a background (only two respondents indicated that they didn't have an economic background). In question 2, respondents were asked to provide an interval for their expectations regarding headline CPI inflation[5] over the next two years after Janet Yellen begins her appointment as chair of the Federal Reserve, which we refer to as the 'baseline' scenario. In question 3, respondents were asked to provide an interval under the assumption that Ben Bernanke would remain at that post, the 'counterfactual' scenario. For question 4 we randomly assigned participants to one of four groups as detailed in Table 1. We asked participants to report the probability (in %) that average headline inflation would be below (groups 1 and 3) or above (groups 2 and 4) the midrange of the interval that they provided in questions 2 and 3, if Ben Bernanke had remained chairman (groups 1 and 2), or under Janet Yellen (groups 3 and 4).

The political framing of the questions was intended to prevent participants from answering the survey as if it were a purely technical inquiry. We anticipated that most of the respondents in our sample would be well aware of different methods for estimating inflation, and we intended to put the focus on a real–world scenario instead of methodological aspects. Questions 2 and 3 were posed on the same survey page so that respondents directly saw that they needed to provide two intervals, one for Janet Yellen as chair, and one for Ben Bernanke as chair.

Our randomization strategy in question 4 corresponds to a between-subjects design. An alternative method would have been to ask every respondent to give the probability of inflation being below or above their interval midrange in both scenarios or to elicit individual distributions in some other way. We chose the between-subjects randomization strategy instead of a within-subjects design for the following reasons. First, we are only interested in whether expected inflation

which primarily depend on observed inflation, and very long-term expectations, which are usually related to credibility of the central bank's inflation target. The former expectations are arguably unrelated to monetary policy actions, whereas the latter expectations would probably display very low disagreement.

[5]Headline CPI inflation was chosen as a familiar measure of inflation among non-professional forecasters in an effort to avoid additional explanations or any possible sense of intimidation among the respondents.

probability distributions are symmetric and whether asymmetries matter for aggregation, not in the shape of individual distributions. Second, our worry with a within-subjects design was that respondents would be trying to give consistent answers instead of emphasizing their subjective probability for excess risks of higher inflation and lower inflation, respectively. Third, the between-subjects design allowed us to keep the survey very short, which we thought would help us reach a higher response rate.

Table 1: **Survey design**

Question	Group	Wording	Answers
1	all	Do you have a background in economics and/or statistics?	yes/no
2	all	Where do you expect to see average headline inflation* in the U.S. over the next two years after *Janet Yellen* begins her appointment as the new chairman of the Federal Reserve (Fed)?	interval a to b
3	all	Where do you expect to see average headline inflation* in the U.S. over the next two years if *Ben Bernanke* had remained chairman of the Fed?	interval a to b
4	1	Were Ben Bernanke to remain chairman of the Fed, what would be the probability of average headline inflation over the next two years being *below* $(a+b)/2^{\dagger}$?	p
4	2	Were Ben Bernanke to remain chairman of the Fed, what would be the probability of average headline inflation over the next two years being *above* $(a+b)/2^{\dagger}$?	p
4	3	After Janet Yellen takes the helm of the Fed, what is the probability of average headline inflation over the next two years being *below* $(a+b)/2^{\dagger}$?	p
4	4	After Janet Yellen takes the helm of the Fed, what is the probability of average headline inflation over the next two years being *above* $(a+b)/2^{\dagger}$?	p

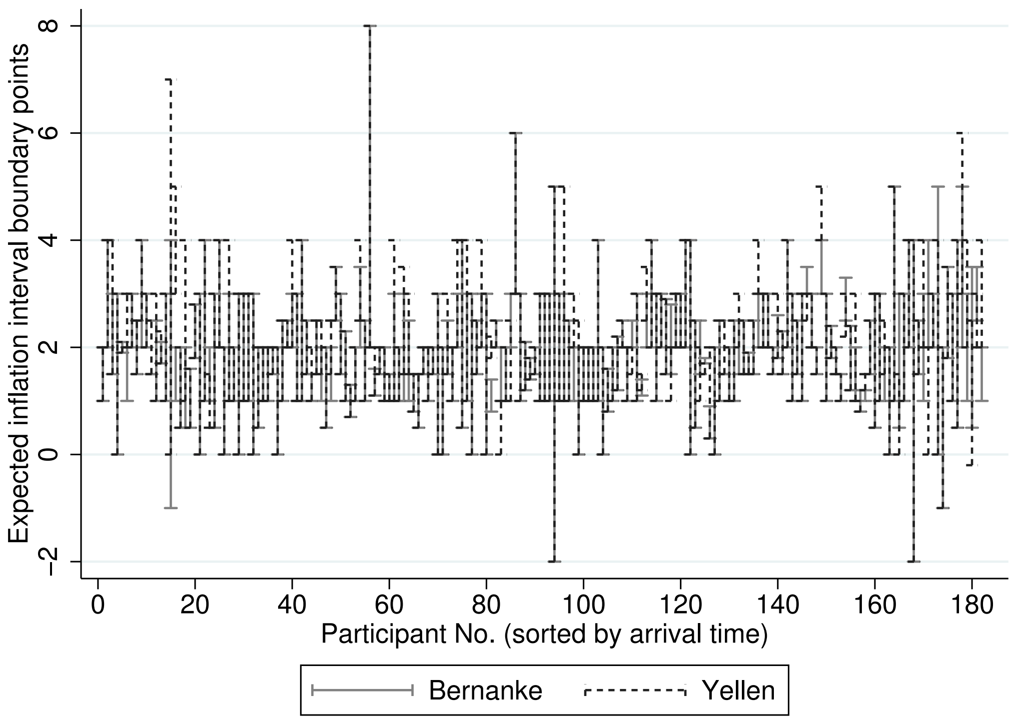
Notes: † $(a+b)/2$ refers to the midrange of the interval provided by respondents in questions 2 and 3, respectively. The sign * denoted a footnote in questions 2 and 3 that stated: "* Annual percentage change in the Consumer Price Index (CPI) released by the U.S. Bureau of Labor Statistics". The respondents were randomly assigned to one of the four groups for question four, as explained in the main text. Both the intervals (questions 2-3) and probability (question 4) were asked in terms of a field where any number could be entered. Small arrows on the side allowed respondents to modify their number upwards or downwards in 0.1 increments.

The 182 respondents completed the survey between December 6, 2013 and February 28, 2014.[6] Figure 1 plots the intervals the respondents provided for the two

[6]This excludes two respondents who indicated that they did not have an economic background,

scenarios, ordered by time at which their response was recorded in the database. Table 2 shows descriptive statistics. Regarding the inflation prediction intervals, we see that they look similar both in terms of spread and midrange, irrespective of whether Janet Yellen or Ben Bernanke were heading the Fed. A few respondents factor in some probability for deflation (negative inflation) in their lower bounds, while some indicate at least a possibility for very high inflation (8%). The midranges are close to two percent. The mean indicated probability that average inflation is higher or lower than the midrange is close to 50%. One observation from Table 2 is that there is substantial heterogeneity in subjective distributions among the respondents to our survey. The interval midranges implied by the answers to questions 2 and 3 range from 0.5% to 5% while the probabilities associated with inflation of a certain magnitude range from 0.025 to 0.9, a finding we will return to below.

Figure 1: **Surveyed intervals of expected inflation.**



Notes: The figure reports surveyed intervals for expected inflation across the respondents and conditional on Janet Yellen (dashed black line) or Ben Bernanke (solid gray line) being Fed chair. The respondents (x-axis) are ordered by time at which we received their online form.

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three who gave a probability of 0 for inflation below/above their midranges provided, and two who provided an interval of zero width.

Table 2: **Descriptive statistics**

Question	Mean	st.dev.	Min	Max
Q1. Economist (0=no, 1=yes)	1.000	0.000	1.000	1.000
Q2. Yellen lower bound	1.195	0.813	-2.000	4.000
Q2. Yellen upper bound	2.835	1.032	1.000	8.000
Q2. Yellen midrange	2.015	0.738	0.500	5.000
Q3. Bernanke lower bound	1.148	0.752	-2.000	3.000
Q3. Bernanke upper bound	2.684	0.917	0.900	8.000
Q3. Bernanke midrange	1.916	0.638	0.500	5.000
Q4. Probability	0.496	0.170	0.025	0.900
Observations	182			

Finally, in Table 3, we check whether our randomization strategy worked, by comparing answers to questions 2 and 3 among our four groups. Note that randomization only affected question 4, so there should not be a statistically significant difference in answers to the previous questions. Group sizes are similar and close to 50. Lower and upper bounds of the inflation intervals, as well as the midranges of the intervals are similar for the four groups. In column 4 of Table 3, we report p-values for the Kruskal-Wallis rank-sum test, a test whether the distributions of answers of the four groups are from the same population. In column 5 of Table 3 we report p-values for the Wald test when regressing answers on group indicator variables. The p-values are well above any usually accepted significance level, which suggests that assignment to a group was not related to previous answers.

We conclude from these results that our randomization strategy worked.

Table 3: **Randomization**

	Mean answer					
Question	Group 1	Group 2	Group 3	Group 4	P > $\chi^{2\dagger}$	P > F‡
Q2. Yellen lower bound	1.255	1.183	1.030	1.318	0.434	0.383
Q2. Yellen upper bound	2.995	2.937	2.650	2.745	0.509	0.355
Q2. Yellen midrange	2.125	2.060	1.840	2.032	0.275	0.306
Q3. Bernanke lower bound	1.162	1.154	1.016	1.259	0.565	0.509
Q3. Bernanke upper bound	2.817	2.798	2.548	2.559	0.471	0.326
Q3. Bernanke midrange	1.989	1.976	1.782	1.909	0.431	0.399
Observations	42	52	44	44	182	182

Notes: † Column "P > χ^2" reports the p-value for the Kruskal-Wallis rank-sum test for whether the distributions of the four groups are from the same population. ‡ Column "P > F" reports the p-value for the Wald test when regressing question answers on group indicator variables. If belonging to a group had explanatory power regarding questions 2 and 3, this value should be low (e.g. below 0.05).

3 Results

This section starts by analysing the asymmetry of subjective probability distributions. We then ask whether there are systematic patterns between asymmetry and intervals of expected inflation in subsection 3.2. Next, we assume a parametric subjective distribution and look how asymmetry relates to its moments in subsection 3.3. Finally, we analyse the aggregate distribution of inflation expectations and briefly address the differences between provided intervals conditional on who the Fed chair is in the last two subsections.

3.1 Asymmetry in subjective distributions

Are subjective inflation expectation distributions symmetric? Using the results from our survey, we can directly test this question. We asked respondents for the probability that US headline inflation would be below (groups 1 and 3) and above (groups 2 and 4) the midrange of the interval they provided, respectively.[7] In what follows, we let p_L denote the probability that average headline inflation is *below* the midrange. For groups 1 and 3 $p_L = p$ and we let $p_L = 1 - p$ for groups 2 and 4.[8]

In column (1) of Table 4 we report the percentage of respondents who responded with a probability different from 0.5. Among all respondents, 60.4% thought the probability that inflation would be below/above their midpoint was different from 0.5. Among the four groups to which we randomly assigned respondents, the percentage reporting a probability different from 0.5 ranges from 59.1% to 63.5%.[9] Thus, the majority of our respondents have asymmetric subjective distributions of expected inflation.

[7]For groups 1 and 2 the question referred to the interval provided in question 3 (counterfactual scenario, i.e. Ben Bernanke remains chair); for groups 3 and 4 the question referred to the interval provided in question 2 (baseline scenario, i.e. Janet Yellen becomes chair). For details see Section 2.

[8]This holds exactly if the subjective distribution of expected inflation has a continuous cumulative probability density function, which is a standard assumption in the literature.

[9]Coincidentally, in both groups 3 and 4, 18 respondents answered with $p_L = 0.5$ and 26 respondents with $p_L \neq 0.5$.

Table 4: **Asymmetry in Inflation Expectations**

Sample	Obs.	share with $p_L \neq 0.5$	95% CI	Mean absolute dev. from $p_L = 0.5$ (excl. $p_L = 0.5$)	Mean p_L	Mean p_L (excl. $p_L = 0.5$)
		(1)	(2)	(3)	(4)	(5)
All	182	0.6044	[0.5334, 0.6754]	0.1939	0.5027	0.5044
				(0.0096)	(0.0126)	(0.0209)
Group 1	42	0.5952	[0.4468, 0.7437]	0.1940	0.5060	0.5100
				(0.0192)	(0.0260)	(0.0440)
Group 2	52	0.6346	[0.5037, 0.7655]	0.2153	0.5132	0.5208
				(0.0196)	(0.0270)	(0.0427)
Group 3	44	0.5909	[0.4456, 0.7362]	0.1904	0.4916	0.4858
				(0.0168)	(0.0244)	(0.0415)
Group 4	44	0.5909	[0.4456, 0.7362]	0.1700	0.4982	0.4969
				(0.0198)	(0.0231)	(0.0393)

Notes: This table reports results for the question(s) "Were [...] chairman of the Fed, what would be the probability of average headline inflation over the next two years being below/above $(a+b)/2$?" where a and b denote the endpoints of the interval the respondent provided in question 2/3 (see Section 2 for details). We denote by p_L the probability reported or implied for average inflation to fall below the interval midrange. Column (1) reports the share of respondents who answered $p_L \neq 0.5$, column (2) reports approximate 95% confidence intervals for this estimate if treated as a Bernoulli variable (where success is defined as $p_L \neq 0.5$), column (3) reports the mean absolute deviation from $p_L = 0.5$ for respondents who indicated $p_L \neq 0.5$ and the associated standard error, column (4) reports the mean and standard error of p_L, column (5) reports the same but excluding cases where $p_L = 0.5$.

If we treat the probability our respondents supplied as a Bernoulli variable, taking on 1 if $p_L \neq 0.5$, and 0 if $p_L = 0.5$ with a 'success rate' r, then column (1) reports an estimate of $\hat{r}$ and we can calculate approximate normal confidence intervals for $\hat{r}$, reported in column (2). The bounds of our confidence intervals are away from 0 (everybody has symmetric expectations) and 1 (everybody has asymmetric expectations). For the whole sample, the confidence interval excludes 0.5 and the corresponding z-test against $H_0 : r = 0.5$ rejects at the 1% significance level. Is the share of respondents with asymmetric expectations the same in the four groups? To answer this question, we carried out the Kruskal-Wallis equality-of-population rank test adjusted for ties. The associated χ^2 statistic is 0.362 (p-value 0.9480). Thus, we cannot reject that the four groups come from the same population.

Furthermore, it did not seem to matter whether we asked respondents about the probability of inflation below (groups 1 and 3) or above (groups 2 and 4) the midrange of the provided interval. The difference in p_L between groups 1 and 3 and groups 2 and 4 is -0.7697 with a standard error of 2.5207 (the p-value of a two sided test against zero is 0.760). In terms of asymmetry of respondents' subjective distributions it also did not seem to matter whether we asked about the baseline scenario (Janet Yellen becoming chair, groups 3 and 4) or the counterfactual scenario (Ben Bernanke remaining chair, groups 1 and 2). The difference in p_L between groups 3 and 4 and groups 1 and 2 is -1.5060 with a standard error of 2.5134 (p-value 0.55).

Testing whether the probability is exactly equal to 0.5 does not take into account the possibility that reported asymmetries could be very small. All respondents who report $p_L \neq 0.5$ could deviate only trivially, since we did not provide them with categories or a scale for their answers. For example, the reported probability could be 0.5001, which would clearly not constitute a meaningful deviation. To get a sense of how far our respondents' subjective probability distributions of expected inflation deviate from symmetry, we report the mean absolute deviation from $p_L = 0.5$ for the respondents who answered $p_L \neq 0.5$ in column (3) of Table 4. For the whole sample, this is 0.1939 and statistically different from 0 at any conventional significance level. In each of the randomly assigned sub-samples, the deviation is large and strongly significantly different from 0.

From the results presented so far, we conclude that subjective inflation expectations are asymmetric for about 60% of our respondents and that the deviation from symmetry is sizeable. This result mirrors similar findings by García & Manzanares (2007) in the SPF, and Pfajfar & Žakelj (2016) in an experimental setting.[10] The advantage of our survey setting is that we directly asked respondents about symmetry. Compared to the literature analysing the SPF, we thus make no functional form assumptions about subjective distributions and face measurement error issues to estimate the degree of (a)symmetry of inflation expectations.

In columns (4) and (5) of Table 4 we report the average probability that inflation is below the midrange for the whole sample and for respondents who answered with $p_L \neq 0.5$, respectively. Despite significant asymmetry in the subjective distributions of our respondents, the probability that inflation is below the midranges implied by their confidence intervals is *on average* close to 50%. In our sample of economists and at this particular point in time, there is no systematic skew in

[10] Specifically, García & Manzanares (2007, p.19) report that "more than 60% of the SPF individual probability forecasts have skewness index γ_1 higher than 0.3 (in absolute value)." Pfajfar & Žakelj (2016, p.850): "For the latter case, we find that only 12.5% of reported confidence intervals are symmetric."

subjective distributions towards the lower or upper end of intervals of expected inflation.

3.2 Asymmetry and Intervals of Expected Inflation

We next turn to analyzing whether there are systematic patterns in the asymmetry of respondents' subjective distributions of expected inflation. To have as much statistical power as possible, we pool responses from the two scenarios (baseline and counterfactual). This means our sample in what follows consists of the intervals provided in question 2 (baseline, i.e. Janet Yellen becomes chair) for groups 3 and 4, and question 3 (counterfactual, i.e. Ben Bernanke remains chair) for groups 1 and 2. For all respondents in this sample we thus have an interval of expected average headline inflation in 2014-2015 and the probability assigned to inflation falling below the interval's midrange (either directly from question 4 or implied by $p_L = 1 - p$). We conducted all analyses that follow for the sub-samples of respondents in the two scenarios and found qualitatively similar results with lower statistical significance.[11]

Table 5 shows summary statistics (mean and standard deviation) of our measures based on the intervals for the full sample (column 1), respondents with $p_L = 0.5$ (column 2), respondents with $p_L \neq 0.5$ (column 3), respondents who indicated that they had a right-skewed (column 4) and left-skewed distribution (column 5), respectively. Respondents who have an asymmetric distribution of expected inflation tend to have higher midranges and narrower intervals, which appears to be mainly driven by higher lower bounds of their intervals. We cannot statistically reject, however, that the differences are zero. Thus, there does not appear to be a systematic relationship between interval measures and whether or not respondents report a probability of inflation falling below their midrange different from 0.5.

[11]Results are available from the authors upon request.

Table 5: **Asymmetry and interval measures**

Sample	all	symmetric vs asymmetric $p_L = 0.5$	$p_L \neq 0.5$	Diff. (3)-(2)	right- vs left-skew $p_L > 0.5$	$p_L < 0.5$	Diff. (6)-(5)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Interval midrange	1.9596	1.8708	2.0177	0.1469	2.1453	1.8991	-0.2462
	(0.6706)	(0.6689)	(0.6683)	*0.1490*	(0.7241)	(0.5940)	*0.0548*
Interval width	1.5885	1.6222	1.5664	-0.0559	1.3321	1.7842	0.4521
	(1.0791)	(1.1413)	(1.0412)	*0.7387*	(0.9308)	(1.0979)	*0.0214*
Interval lower bound	1.1654	1.0597	1.2345	0.1748	1.4792	1.0070	-0.4722
	(0.7866)	(0.8125)	(0.7650)	*0.1481*	(0.7017)	(0.7566)	*0.0010*
Interval upper bound	2.7538	2.6819	2.8009	0.1190	2.8113	2.7912	-0.0201
	(0.9289)	(0.9413)	(0.9221)	*0.4017*	(0.9947)	(0.8578)	*0.9102*
Observations	182	72	110	182	53	57	110

Notes: Columns 1-3 and 5-6 show means and standard deviations for the full sample and by p_L provided by respondents. Column (4) is the difference between columns (2) and (3) (symmetric vs asymmetric). Column (7) is the difference between columns (5) and (6) (right-skew vs left-skew). Numbers in parentheses are standard deviations. Numbers in italics are p-values of a two-sided test against zero.

Columns 5-7 of Table 5 compare interval measures between respondents with right- and left-skewed distributions, respectively. The midrange is 0.25 points lower among respondents with left-skewed ($p_L < 0.5$) compared to those with right-skewed expectations. This difference is weakly statistically significant with a p-value of the two-sided test against zero of 0.055. However, the (non-parametric) Kendall's tau rank correlation between the midrange and p_L is 0.0876 with a p-value of 0.1195. From our sample, we cannot conclude that there is a statistically significant relationship between the midrange and p_L.

In principle, the positive relationship between the level of expected inflation and asymmetry could matter for aggregating inflation expectations. If respondents with left-skewed expectations systematically expect lower inflation than respondents with right-skewed expectations, the aggregate distribution would have much less probability mass in the tails than otherwise.

Finally, Table 5 also shows that intervals are on average 0.45 points wider among respondents with left-skewed compared to respondents with right-skewed expectations and the difference is statistically significant. However, we note that this finding does not translate into a robust negative association between interval width and the probability mass respondents put below their midrange. The correlation between interval width and p_L is -0.1 among respondents with $p_L \neq 0.5$ and not statistically significantly different from zero (p-value 0.17).

This is another channel through which asymmetry of subjective distributions could matter for the aggregate distribution. If more uncertain forecasters attach systematically more probability on inflation overshooting their midrange, *ceteris paribus*, the mean of the aggregate distribution should be higher than otherwise. In the absence of systematic relationships between asymmetry and the interval measures, it is not surprising that asymmetry of subjective distributions does not matter much for the aggregate distribution in our sample.

3.3 Parametric analysis

In this section, we impose parametric assumptions on the subjective distributions of expected inflation. We have two goals in mind. First, we want to assess to what degree asymmetry is related to moments of individual distributions. Second, we want to aggregate the individual responses into one distribution of expected inflation. Both require a functional form assumption on individual distributions.

Common distributions in the literature studying the SPF are the normal distribution, the unimodal generalized beta and skew-normal distributions for responses comprising more than two intervals, and the triangular distribution for responses with two intervals or one interval.[12] Our survey differs from the SPF in that it results in only two bins with variable widths. Therefore, we choose a different approach and assume that the probability densities are piecewise uniform.[13] We also experimented with triangular and skew-normal distributions. Qualitatively, the results are very similar under these alternative distributional assumptions.[14]

[12]See Engelberg et al. (2009) for a comprehensive discussion

[13]See Diebold, Tay & Wallis (1999) who make this assumption for the individual bins in the SPF histograms.

[14]Regarding the triangular, unlike Engelberg et al. (2009), we do not assume individual distributions are symmetric when a respondent provides probabilities in two bins. This implies the triangular distribution is not able to fit the responses of all our respondents, but only those who answered with $0.25 \leq p_L \leq 0.75$ (86%). Ignoring this problem (setting $p_L = 0.25$ and $p_L = 0.75$ for affected data points, respectively) we obtain very similar results to our main result. The only difference is that the variances of individual and aggregate distribution are smaller, as one would expect. These results are available upon request.

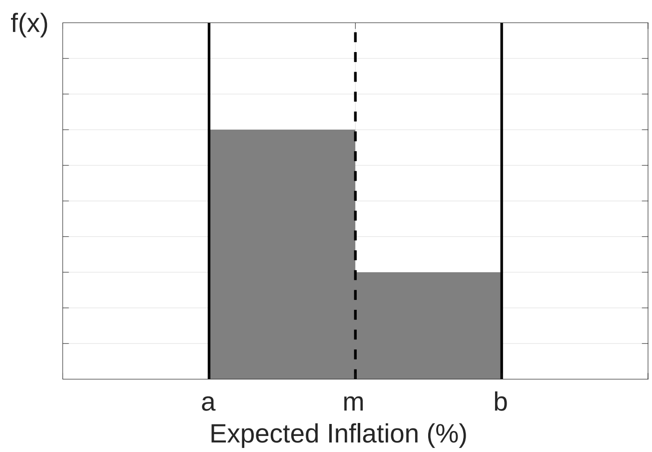
More specifically, we assume subjective distributions of expected inflation are a finite mixture of uniform distributions $U(a,m)$ and $U(m,b)$ with mixing probabilities given by p_L and $p_U = 1-p_L$, respectively, where p_L is the probability assigned to average inflation falling below the midrange of the provided interval (see discussion in Section 3.1 above). Therefore, we assume 100% coverage ratio for the intervals provided by our respondents.[15]

The subjective distribution of respondent i thus follows the piecewise-uniform probability density function $f_i(x)$ given by

$$f_i(x) = \begin{cases} \frac{p_{iL}}{m_i - a_i} & \text{if } a_i \leq x < m_i \\ \frac{1-p_{iL}}{b_i - m_i} & \text{if } m_i \leq x \leq b_i \end{cases}$$

and zero elsewhere. Figure 2 illustrates the idea. This distribution is fully specified by the bounds of the interval (a_i and b_i, from which we calculate the midrange m_i), and p_{iL}, the probability assigned to inflation falling below m_i. It is able to fit the answers of all respondents in the sample.

Figure 2: **Piecewise Uniform Example**



Notes: The figure depicts the piecewise uniform for a respondent who provided interval boundaries a and b. The area to the left of m (the interval midrange) is what we denote by p_L and corresponds to the probability (or one minus the probability) supplied in question 4.

Given $f_i(x)$ the mean (μ_i) and median of the piecewise uniform are given by

[15] In our case, the coverage ratio is arguably does not very important since we are interested in the asymmetry of individual responses. However, the aggregate distribution could change if the coverage ratios are different across respondents *and* correlated with the moments of their subjective distribution. Since we presented all our respondents with the same question regarding the intervals, we cannot test this assumption.

$$\mu_i = \frac{1}{2}\left[p_{iL}(m_i + a_i) + (1 - p_{iL})(m_i + b_i)\right]$$

$$\text{median}_i = \begin{cases} m_i + \frac{0.5 - p_{iL}}{1 - p_{iL}}(b_i - m_i) & \text{if } p_{iL} < 0.5 \\ a_i + \frac{0.5}{p_{iL}}(m_i - a_i) & \text{if } p_{iL} \geq 0.5 \end{cases}$$

Let $X_L \sim U(a_i, m_i)$ and $X_U \sim U(m_i, b_i)$ denote the part of the distribution to the left and right of m_i with weights given by p_{iL} and $p_{iU} = 1 - p_{iL}$, respectively. The means of the two parts are simply $\mu_{iL} = (a_i + m_i)/2$ and $\mu_{iU} = (m_i + b_i)/2$. The r-th central moment of the component mixture of respondent i is then given by

$$E\left[(X - \mu_i)^r\right] = \sum_{j \in \{L,U\}} \sum_{k=0}^{r} \binom{r}{k} (\mu_{ij} - \mu_i)^{r-k} p_{ij} E\left[(X_j - \mu_{ij})^k\right]. \qquad (1)$$

which helps us calculate the variance and skewness of the piecewise uniform for every respondent. Table 6 reports averages and standard deviations of the piecewise uniform means, medians, variances, and skewness for the full sample and for groups of respondents formed according to the p_L they provided.

Despite the substantial degree of asymmetry in individual expected inflation documented in Section 3.1 above, the piecewise uniform means and medians are on average close to the midranges reported in Table 5. We also find that respondents with left-skewed expectations have significantly higher variances, similarly to the results on interval widths presented in Table 5.[16] While there is a substantial asymmetry in the subjective distributions of inflation, these asymmetries balance each other out on average. The average skewness of the piecewise-uniform distributions is very close to zero among respondents with $p_L \neq 0.5$ and close to ± 0.5 among respondents with $p_L > 0.5$ and $p_L < 0.5$, respectively.

[16]Once again, this finding does not translate into a robust negative relationship between uncertainty and skewness. The (linear) sample correlation between variances and skewness of the piecewise-uniform distributions is -0.0665 and not statistically significant at any conventional level.

Table 6: **Asymmetry and parametric measures of individual expected inflation**

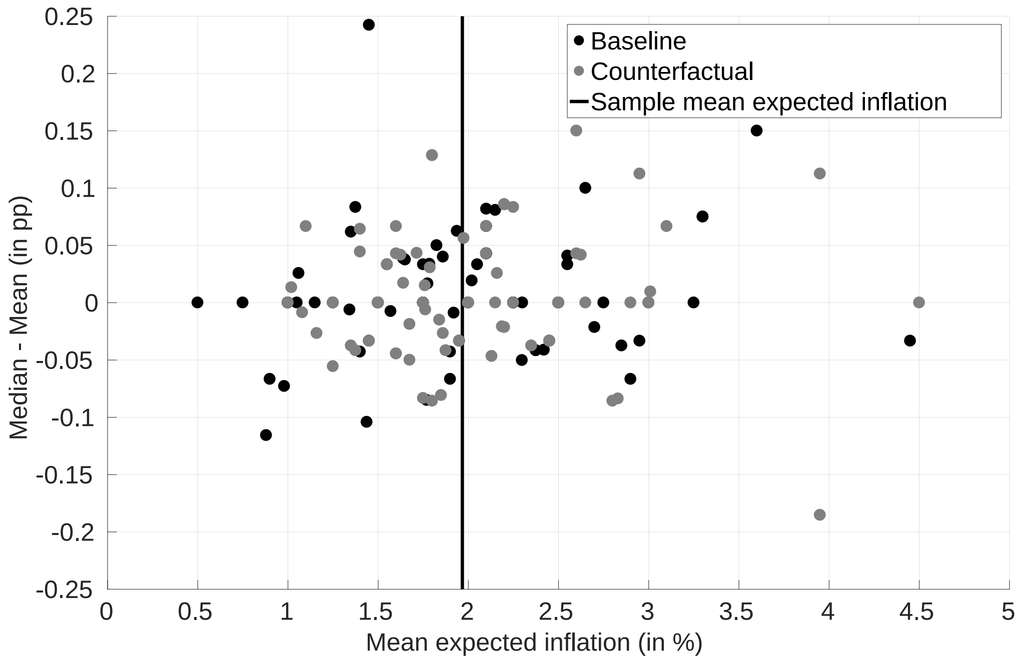
Sample	all	$p_L = 0.5$	$p_L \neq 0.5$	Diff. (3)-(2)	$p_L > 0.5$	$p_L < 0.5$	Diff. (6)-(5)
		symmetric vs asymmetric			right- vs left-skew		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
PWU mean	1.9668	1.8708	2.0297	0.1588	1.9956	2.0613	0.0657
	(0.6611)	(0.6689)	(0.6513)	*0.1152*	(0.6909)	(0.6167)	*0.6009*
PWU median	1.9723	1.8708	2.0388	0.1680	1.9491	2.1222	0.1732
	(0.6667)	(0.6689)	(0.6598)	*0.0976*	(0.6862)	(0.6289)	*0.1715*
PWU variance	0.2768	0.3263	0.2444	-0.0819	0.1660	0.3173	0.1513
	(0.4642)	(0.5681)	(0.3808)	*0.2836*	(0.2724)	(0.4495)	*0.0336*
PWU skewness	0.0027	-0.0000	0.0045	0.0045	0.5270	-0.4813	-1.0082
	(0.4378)	(0.0000)	(0.5642)	*0.9333*	(0.2534)	(0.2478)	*0.0000*
Observations	182	72	110	182	53	57	110

Notes: Columns 1-3 and 5-6 show means and standard deviations for the whole sample, symmetric and asymmetric respondents, and respondents with $p_L > 0.5$ and $p_L < 0.5$, respectively. Column (4) shows the difference between columns (2) and (3). Column (7) shows the difference between columns (5) and (6). Numbers in parentheses are standard deviations. Numbers in italics are p-values of a two-sided t-test against zero.

On the whole, there does not appear to be a significant relationship between asymmetry and the level of expected inflation as expressed in mean and median of the subjective distribution, although we find a statistically weak difference between respondents with $p_L = 0.5$ and $p_L \neq 0.5$ in medians, see Table 6. To illustrate this point, Figure 3 plots the difference between piecewise uniform means and medians, one proxy for asymmetry, against mean expected inflation. The associated regression gives a slope coefficient of -0.0056 with a standard error of 0.0057.

Summing up the findings in this section, we see substantial asymmetries in subjective distributions of expected inflation. On aggregate, however, these asymmetries average out. We find little evidence for systematic relationships between asymmetry of a forecaster's distribution and measures of central tendency of inflation expectations. Just as there is substantial disagreement between forecasters with regards to expected inflation, there is substantial disagreement with regards to how likely it is that inflation falls into certain ranges. We do find a tendency that respondents who provided wider intervals (more uncertainty) have left-skewed distributions. We next look at aggregation and whether accounting for asymmetry

Figure 3: **Asymmetry and Expected Inflation**



Notes: The figure plots mean expected inflation (x-axis) and the median - mean difference (y-axis) for each respondent in the sample together with the sample mean expected inflation (vertical solid line).

of individual distributions matters for the aggregate distribution.

3.4 Aggregate inflation expectations

In this subsection, we develop an aggregate distribution of expected inflation among our sample of economists. We then compare these expectations to the one reported in the outcome of the SPF for Q1 2014. Finally, we discuss the asymmetry of the aggregate distribution of inflation expectations by distinguishing between disagreement among individual respondents and the asymmetry of their subjective probability distributions.

To get an aggregate distribution of our survey respondents, we use the same assumptions as in Section 3.3 above. We assume that individual distributions are piecewise uniform and use the finite mixture distribution to form an aggregate distribution of inflation expectations following Wallis (2005) and Boero, Smith & Wallis (2015). We use equal weights when forming the mixture, so that each of our n respondents has a weight of $1/n$. The probability density function of the mixture distribution is then

$$g(x) = \sum_{i=1}^{n} \frac{1}{n} f_i(x),$$

where $f_i(x)$ denotes the probability density functions of the individual piecewise uniforms. The mean of the aggregate distribution (μ) is then simply the mean of the μ_is we calculated above. Higher moments can be obtained using formula (1) (see Section 3.3 above) forming the outer sum over individual responses and substituting $p_{ij} = 1/n$.

Following this aggregation procedure yields a combined mean expected inflation in 2014 and 2015 of $\mu = 1.95$ for the baseline groups (Yellen becomes chair), $\mu = 1.98$ for the counterfactual groups (Bernanke remains chair), and $\mu = 1.97$ for the full sample, see Panel A of Table 7. These can be compared to the outcome of the SPF released in February 2014.[17] SPF mean expected fourth-quarter over fourth-quarter headline inflation was 1.81% for 2014 and 1.98% for 2015, which corresponds to an annualized average inflation of 1.90% over the two years.[18] The

[17]A complete write–up of the survey is available at http://www.phil.frb.org/research-and-data/real-time-center/survey-of-professional-forecasters/2014/spfq114.pdf.

[18]To get the two year annualized average we calculate the geometric mean of 2014Q4/2013Q4 and 2015Q4/2014Q4 inflation for each SPF respondent and then calculate the average over all

same exercise reveals that median expected inflation in our sample of respondents is also close to median inflation expected by SPF respondents.[19]

Table 7: **Aggregate Distribution and Simulations**

	Full sample	Baseline (Yellen)	Counterfactual (Bernanke)
PANEL A. DATA			
Mean	1.9668	1.9505	1.9821
CDF at mean	0.5444	0.5350	0.5511
Median	1.8928	1.8981	1.8878
Variance	0.7115	0.7116	0.7109
Skewness	0.6322	0.3834	0.8661
PANEL B. NO ASYMMETRY			
Mean	1.9596	1.9358	1.9819
CDF at mean	0.5375	0.5337	0.5386
Median	1.8953	1.8813	1.9093
Variance	0.7540	0.7046	0.7993
Skewness	0.7252	0.2937	1.0501
PANEL C. NO DISAGREEMENT			
Mean	1.9668	1.9505	1.9821
CDF at mean	0.4990	0.4974	0.5005
Median	1.9677	1.9526	1.9817
Variance	0.2768	0.2557	0.2967
Skewness	0.0187	-0.1144	0.1183
Observations	182	88	94

Notes: The table reports mean, probability mass below mean, median, variance and skewness of the mixture distribution for the full sample (column 1), respondents in the baseline scenario (column 2) and respondents in the counterfactual scenario (column 3). Panel A uses the data from our survey. Panel B reports results if we impose $p_L = 0.5$ before forming the aggregate distribution (no asymmetry for all respondents). In Panel C we first fit the piecewise uniforms and then re-center respondents' intervals so that the means of all respondents are equal to the aggregate mean.

More importantly, the aggregate distribution has a moderate positive skewness of 0.63,[20] which corresponds to patterns seen in the SPF, see García & Manzanares (2007). Skewness is closer to zero in the baseline aggregate distribution as opposed

respondents.

[19]The median expected inflation in our survey is 1.90% (baseline), 1.89% (counterfactual), and 1.89% in the full sample. Median expected headline inflation among SPF respondents was 1.80% for 2014 and 2.00% for 2015. The median annualized average was 1.92% over the two years.

[20]Skewness lower than -1 and higher than 1 is considered high, between -1 and -0.5 or 0.5 and 1 as moderate, and between -0.5 and 0.5 as approximately symmetric, see Bulmer (1979).

to the counterfactual scenario. However, we note that skewness is sensitive to outliers. If we remove respondent 56 from the sample (group 2, $a = 2$, $b = 8$, $p_L = 0.85$), skewness becomes 0.67 in the counterfactual group and 0.52 in the full sample (excluding respondent 56).

3.4.1 A simulation experiment

It may be surprising that the aggregate distribution is somewhat positively skewed given that individual asymmetries seemingly balance each other out, as shown above. But even if subjective distributions were perfectly symmetric, the aggregate distribution could still exhibit asymmetry, because respondents disagree about the level of future inflation. In this section, we conduct a simulation exercise to uncover the importance of asymmetry for the aggregate distribution and disentangle asymmetry from disagreement. We define asymmetry as $p_L \neq 0.5$. As a measure of disagreement, we use differences in mean expected inflation between respondents.[21]

The design of our survey allows us to 'simulate' survey responses as follows. First, we 'switch off' asymmetry by imposing $p_L = 0.5$ for all respondents. Using this simulated sample, we form the aggregate mixture as above and calculate its moments. The results of this exercise are shown in Panel B of Table 7. In a second simulation, we 'switch off' disagreement among respondents by re-centering their intervals so that the means of the individual piecewise uniform distributions are equal to the mean of the aggregate distribution (first row in Panel A of Table 7). The results of this second exercise are shown in Panel C of Table 7.

Switching off asymmetry has little effect on the moments of the aggregate distribution. The mean slightly decreases while the median increases for the full sample. This is in line with the positive association between left skewness and uncertainty discussed in Section 3.3 above. More uncertain respondents tend to put more probability mass above the midrange. Ignoring asymmetry thus leads to a slight underestimate of the aggregate mean, although the difference is small. Variance and skewness of the aggregate distribution also slightly increase when

[21] In the literature studying the SPF, disagreement usually means differences in point predictions. The mean of subjective distributions of expected inflation is one candidate to give rise to point predictions. Our results are not sensitive to whether we use the mean or the median of the individual distributions for this exercise.

we switch off asymmetry.[22] The former is in line with the results discussed in Section 3.3 above. Our respondents' subjective distributions exhibit a tendency to be skewed towards the common mean. Ignoring asymmetry thus implies a slight decrease in precision.

Switching off disagreement (Panel C) has much stronger effects on the higher moments of the aggregate distribution. Now the variance decreases to 0.2768 and skewness is close to zero. These two experiments show that in our sample of economists, disagreement is responsible for skewness (and much of the uncertainty) of the aggregate distribution of expected inflation while asymmetry plays only a minor role. If all the respondents in our survey had given an identical mean expected inflation, the aggregate distribution would have been almost perfectly symmetric despite a high degree of asymmetry in individual responses. This result is in line with our analysis of asymmetry at the individual level above. While there is a substantial degree of asymmetry in the distributions of expected inflation among our respondents, these asymmetries cancel out on average.

Accounting for asymmetry of subjective distributions of expected inflation does not seem overly important based on these results. A simple survey question eliciting interval predictions would contain as much information about mean expected inflation and uncertainty as a question allowing for asymmetry. We caution, however, that this may only be true for this particular point in time and one should be careful when trying to extrapolate this result.

3.5 Ben Bernanke vs Janet Yellen

Preferences of a central banker and therefore the likely path of future interest rates are important determinants of inflation expectations. Even though news reports at the time of our survey portrayed madame chair Yellen as a dovish policymaker,[23] both chairman Bernanke and madame chair Yellen are considered to be consensus-builders[24] in the Federal Open Market Committee (FOMC), and there-

[22]Note that the latter result is quite sensitive to outliers. If we drop respondent 56 from the sample, skewness decreases from 0.52 to 0.36 when we switch off asymmetry (full sample).

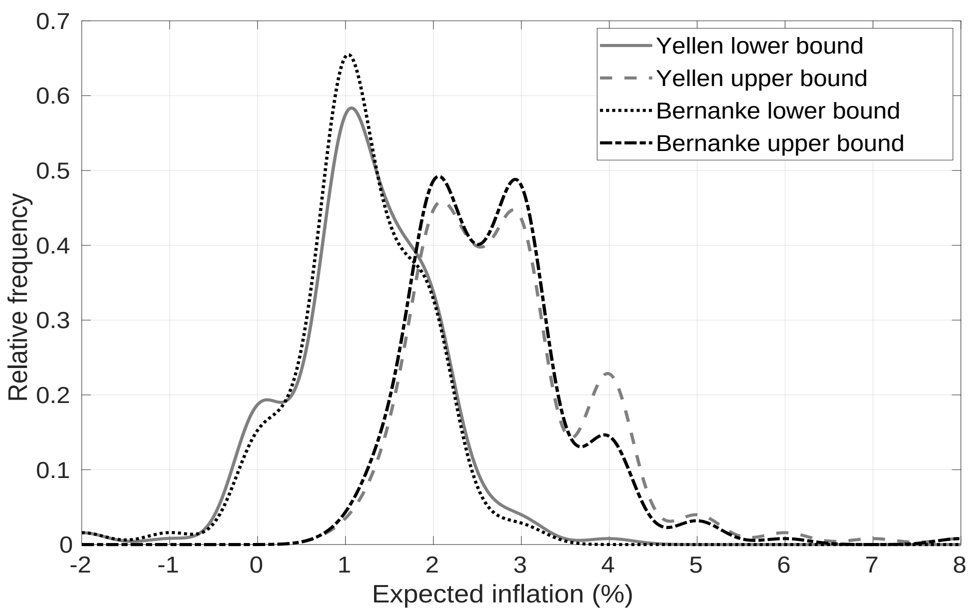
[23]See for example the outcome of the "CNBC October Fed Survey" reported by *Yahoo! Finance* and available at http://finance.yahoo.com/news/yellen-more-dovish-bernanke-survey-182219199.html (retrieved on 30.10.2016.

[24]See for example the news article from *Reuters* available at http://www.reuters.com/article/us-usa-fed-yellen-idUSKCN0SK0C520151026 (retrieved on 30.10.2016).

fore monetary policy in the US should be largely unaffected by who the FOMC chair is.[25]

As a matter of fact, the measures of central tendency shown above are not significantly different between the two scenarios. The majority of respondents (69%) in our sample gave the same interval for expected inflation conditional on who the Fed chair is. We compare the distributions of lower and upper bounds for the two scenarios in Figure 4, which plots kernel densities using a normal kernel. To see whether the distributions are statistically different we use the Kolmogorov-Smirnov test. We could not reject the null hypothesis that the two distributions are statistically the same, with a test statistic of 0.054 (p-value 0.94) for the lower bound and 0.076 (0.64) for the upper bound. Our aggregate distribution does indicate that expected inflation would have been slightly higher if Ben Bernanke had remained at the helm of the Fed. According to Panel A of Table 7, mean expected inflation is 1.9505 under Janet Yellen vs 1.9821 under Ben Bernanke.

Figure 4: **Kernel densities of surveyed intervals.**



Notes: The figure reports estimated kernel densities of lower and upper bound for expected inflation conditional on Janet Yellen (solid gray line) or Ben Bernanke (dashed black line) being Fed chair. The estimate is based on a normal kernel function, using a window parameter (width) that is a function of the given number of points.

[25]We are grateful to an anonymous referee for pointing this out.

4 Conclusion

We conducted a simple survey that directly tests for asymmetry in subjective distributions of expected inflation in the US. Survey results show that about 60% of respondents have asymmetric inflation expectation distributions and that the deviation from asymmetry is large. Interestingly, we find that individual asymmetries balance each other out on average and display no systematic relationship to other moments of subjective distribution. One implication of this result is that using interval midpoints from surveys gives an accurate representation of average expected inflation. This could be augmented by interval length as one possible summary statistic for the degree of uncertainty, although we leave investigations about how well interval length proxies for different measures of uncertainty to future studies.

The aggregate distribution we obtain has a mean that is close to the average point prediction obtained from the Survey of Professional Forecasters in the first quarter of 2014 and a moderately positive skewness. The aggregate skewness seem to be driven by disagreement among respondents and not the asymmetry of their subjective distributions. In fact, disregarding the individual asymmetry completely changes little in terms of mean and variance of the aggregate distribution. We caution that our results reflect expectations at a particular point in time, and that it may well be that our findings depend on the general business cycle situation.

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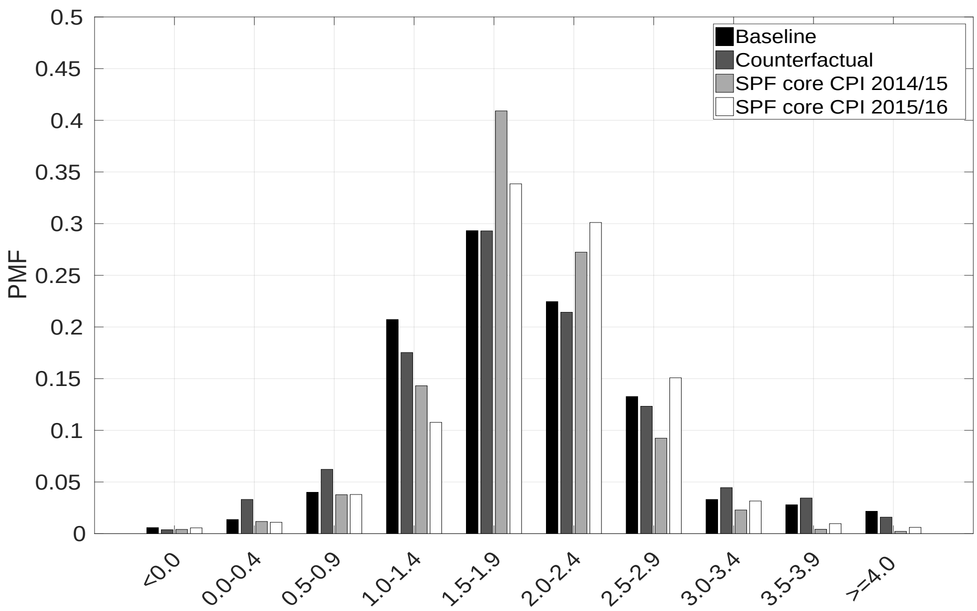
Appendix

Here, we compare the aggregate distribution we obtain from our survey participants to the Survey of Professional Forecasters (SPF). The SPF asks participants to specify probabilities that Core CPI inflation falls into certain bins over a number of different horizons. Since our survey asked about expected inflation over a two year horizon, we compare our aggregate distribution to the SPF one year and two years ahead fourth-quarter over fourth-quarter inflation rates.[26] Note that our results are not directly comparable to the SPF histograms, as headline inflation is more volatile than core inflation. Nevertheless, we argue that this comparison is useful to shed some light on whether our aggregate distribution looks 'reasonable'.

We construct the SPF histograms following the SPF methodology by averaging the individual PMFs within each bin. Using the CDF of our aggregate mixture distribution, we can similarly calculate the aggregate probability our survey respondents assigned to inflation falling into these bins. Figure A.1 shows the result of this exercise. The histograms are roughly comparable in terms of location and shape. As would be expected when comparing headline and core inflation, our respondents assigned more probability to the extremes. We also note that they assigned more probability to comparably low inflation (1% to 1.4%).

[26]For Core CPI the SPF asks the participants to provide "the mean probability that the fourth-quarter over fourth-quarter percent change in falls in a particular range."

Figure A.1: **Comparison to the Survey of Professional Forecasters.**



Notes: This figure compares the histogram of the aggregate mixture distribution of 'baseline' groups 3 and 4 (see Table 1) and 'counterfactual' groups 1 and 2 to the annual (Q4 over Q4) Core CPI inflation forecasts for 2014 and 2015 from the Survey of Professional Forecasters released in February 2014.